Effects of Road Culverts on Eastern Montana Prairie Fish Assemblages

Research Proposal – November 2005

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Abstract

Road culverts can serve as significant obstacles to fish migrating between seasonal habitats. The development of new roads, as well as the repair and upgrade of existing roads has led to substantial research addressing the effects culverts have on fish populations. The majority of this research has focused on salmonid species in mountain stream systems, but the total effect road culverts have on species continuity in small, prairie streams remains largely unknown. This study proposes to investigate the effects road culverts have on prairie fish assemblages in the lower Yellowstone River drainage. Because many of the diverse number of fish species found in prairie streams are small bodied, and likely poor swimmers, culverts may act as more significant barriers than towards salmonid species. Culvert characteristics that limit passage include outlet drop, high water velocity, and insufficient water depth. My objectives for this study are: 1) The FishXing model will be used to assess fish passage through road culverts in prairie streams. The results from this model will be used to examine which hydraulic characteristics are limiting the abilities of prairie-fish. The results will also be compared to the observed passage abilities from direct assessment. 2) Fish passage ability will be directly assessed through culverts at different water levels. Culvert characteristics will be examined in relation to passage of fish species. This resulting data will be used to examine if fish passage is influenced by species, fish size, water velocity, outlet drop, temperature, and culvert material. This information will also be used to validate the results from Objective 1. 3) We will also examine the longitudinal distribution of fish within these tributaries. By examining species composition along the length of the drainage, we will determine if culverts are limiting the distribution of certain fish species.

The proposed project area lies near the town of Glendive, in eastern Montana. Several tributaries of the Yellowstone River with a variety of culvert crossings will be examined. Passage abilities of prairie-fish species will be assessed indirectly, as well as directly through the use of mark-recapture experiments. These experiments involve capturing fish using seines, marking fish with Visual Implant Elastomer (VIE) tags, and placing them downstream of a road culvert to assess upstream movement numbers. An identical control reach will be established downstream from the experiment. The streams will be equipped with data logging instruments that will reflect the discharge of water for the duration of these experiments. Longitudinal distribution of fish species will be examined by sampling fish populations with seines in several reaches throughout each system.

This study will ultimately provide insight into the effects culverts are having on an assemblage of fish that not only represents a recreational resource, but also contributes the overall diversity of a "healthy" ecosystem. Fish managers and engineers alike could also gain valuable information on the relationships of culvert type and discharge on fish passage efficiency. This could lead to more effective culvert designs and installations.

Introduction

Culverts are currently the most cost effective means of crossing streams for transportation. Forest roads used for recreation and timber practices routinely cross tributaries in headwater systems. Similarly, culverts are also commonly used in prairie systems where roads are maintained for transportation and agricultural purposes. The large number of tributaries found within both of these types of systems makes construction of bridges for each crossing economically unrealistic. The advantages of using culverts, in addition to material cost, also include ease of installation, and wide-range applicability. However, concern over the implications to fish passage has led to considerable research. Studies have shown that culverts can act as upstream migration barriers to various species of fish for a host of reasons (Belford and Gould 1989; Gibson et al. 2005; Warren and Pardew 1998). Hydraulic characteristics that can prevent upstream movement of fish include high water velocities, large outlet drops, low water depths during dry periods, lack of resting habitats both within the culvert and in the downstream plunge pool, and disorienting turbulent flows (Furniss et al. 1991). The biological repercussions of these hydraulic factors are different for each of the species that inhabit small streams.

Historically, much of the emphasis of road culvert studies has been placed on salmonid species in mountain stream systems. This is probably due to the economic and ecological implications of restricted fish passage to highly migratory species. For example, Pacific salmon have been widely studied due to their reduction of habitat from years of coastal development, hydroelectric facilities, and timber practices (Smith et al. 1998). These fish easily justify the need for research based on the economic value they create from commercial fishing and tourism, and the ecological role they play on many levels including biological diversity, and nutrient additions to sterile, forest systems. In recent years, additional efforts have also been placed on providing passage for several inland salmonids as well (Belford and Gould 1989). Migrant species such as bull trout *Salvelinus confluentus*, which was listed as threatened under the United States Endangered Species Act in 1998, have prompted the need for passage related research to remedy the effects of road densities throughout their native distribution (Baxter et al. 1999). However, research on the effects of culvert barriers on prairie-fish assemblages remains relatively scarce. In a review of the literature, I found only one study that examined the passage implications culverts have on small, prairie fish (Warren and Pardew 1998). While these fish do not hold the same economic value that their salmonid relatives do, they do contribute to the overall biologic diversity of prairie systems, and are commonly preyed upon by the larger, downstream piscivores that do hold an economic value. Additionally, many of the small, stream-dwelling fish found in these prairie environments make up a large portion of the native fish found in Montana.

Studies on the effects of upstream barriers on warm-water fish, while limited, do exist however. Several studies have examined the effects of water velocity and fishway design (Schwalme et al. 1985; Bunt et al. 2001) for large-river warm-water fish. This research has shown that these fish exhibit a strong, upstream migratory behavior, and that certain critical velocities can prevent fish from passing through man-made obstructions. The direct implications of culverts as barriers in warm-water systems are limited in the current literature. However, mark-recapture techniques were used to examine the effects of four different types of stream crossings on small streams in Arkansas (Warren and

Pardew 1998). In addition to showing that fish movement does exist in these systems, they also found that fish movement was an order of magnitude lower through culverts than other types of crossings and natural reaches.

Research on passage abilities of warm-water fish species has typically been done through direct observation. These studies have employed techniques such as mark-recapture (Warren and Pardew 1998), passive integrated transponder (PIT) tag technology (Haro et al. 2004), and trapping upstream migrating fish (Schwalme et al.1985). The use of indirect measures, such as software models, appears to be limited in small, warm-water streams. However, FishXing (Six Rivers Watershed Interactions Team 1999), a software model designed by Humboldt State University researchers, is readily available for use in these situations. This model uses physical and hydraulic characteristics of a culvert, in combination with the biological capabilities of fish, to indirectly assess the passage capabilities of the culvert of interest. Many of the fish used in the software are commonly found in both large and small warm-water streams. A combination of direct and indirect assessment techniques was used to examine fish passage through culverts for salmonid species in the Clearwater River drainage in western Montana (Burford 2005). The results of these observations were used to validate the findings of the FishXing model. In several cases, culverts were determined to be barriers by the model, but readily passed fish upon direct observation. This study will similarly use a combination of mark-recapture techniques, as well as the FishXing model to assess passage limitations of prairie-fish in eastern Montana.

Culverts as Barriers

Culverts can create hydraulic conditions that alone, or in combination can result in upstream migration barriers for fish species. These characteristics are commonly exacerbated by improper design, under-sizing, and improper installation (Furniss et al. 1991). The following are discussions of the ways in which these hydraulic characteristics can affect upstream movement by fish.

Water Velocity

Water velocity can limit the successful passage of fish if it exceeds the swimming capability of the species of interest. Katapodis and Gervais (1991: page 1) state that "the main problem with improperly designed and installed culverts is that they form velocity barriers to fish migrants at the outlet, inlet or through the culvert barrel." Water velocity is directly related to the dimensions, slope, and material of the culvert, thus making proper design and implementation essential to "fish friendly" culverts.

Katapodis and Gervais (1991) describe three types of swimming speeds fish regularly display: sustained, prolonged, and burst. Sustained speed is described as a speed maintained indefinitely, prolonged speed is considered a moderate speed that can be maintained for up to 200 minutes, and burst speed is described as the maximum attainable speed maintained for less than 15 seconds. They further describe prolonged speed as the type of swimming fish use to pass culverts without stopping. However they also make clear that some fish may also use burst and rest techniques to take advantage of slower velocity areas caused by the culvert material. Because of inconsistencies in culvert materials, we will use the situation in which fish swim continuously through a culvert to define critical velocities for fish passage. Therefore, we can assume that if water velocities exceed that of the prolonged swimming capability of a certain species, then passage may be impaired. Katapodis and Gervais (1991) compiled over 500 references on these critical velocities for fish swimming performance, and have created a database containing the results of previous studies. An extensive list of freshwater and anadromous fish is included in the database. This information could allow researchers to compare findings from direct observations to previous studies on similar species.

Outlet Drop

The outlet drop height of water exiting the culvert to the stream below can limit the passage of fish if it exceeds the fish's jumping capabilities. Outlet drops below culverts can be the result of improper installation, or consequences of scouring associated with the culvert itself. Observations of salmon jumping up waterfalls are widespread, and some research has examined the jumping abilities of inland salmonids (Kondratieff and Myrick 2005). However, the jumping abilities of warm-water fish, particularly cyprinids, are relatively unknown. Furniss et al. (1991) recommend culvert outlet drops not to exceed 0.3 m for adult trout, and 0.6-0.9 m for adult salmon and steelhead. Considerations like these for prairie fish species are not readily available. However, because prairie fish evolved in low gradient systems, we might expect them to have lower jumping capabilities than salmonids.

Insufficient Water Depth

The depth of water within the culvert barrel can restrict the passage of fish if it becomes too low for fish to effectively swim in. Furniss et al. (1991) recommends minimum water depths of 0.15 m for trout, and 0.3 m for salmon and steelhead. However, recommendations like these are not readily available for prairie fish. Preliminary investigations have shown that small streams are routinely fit with large culverts when permanent, high-use roads (E.g. interstate highways) cross them. Culverts like these are commonly sized to accommodate high flow events associated with the flashy nature of the prairie environment. During dry months, these large culverts may create low-flow conditions making fish passage difficult. Culverts should generally be sized to accommodate high-flow events, but small enough to retain sufficient depth for fish passage.

Resting Areas

Resting areas, both inside the culvert, and in the plunge pool below, can also influence successful passage. Culvert materials typically account for resting areas found within the culvert barrel. Different bottom types create varied channel roughness, which leads to subtle changes in water velocity near the bottom. At some flows, fish can use these lower velocities for resting, but at higher flows, this channel roughness may cause turbulent conditions unfavorable to fish (Furniss et al. 1991).

The plunge-pool created by the scouring effect of water leaving the culvert barrel also affects the rate of fish passage. These pools must be sufficiently deep to accommodate fish's jumping requirements if an outlet drop exists. Preliminary investigations have shown that concrete aprons and other scour-preventing measures are often installed below culverts within the proposed study area. These measures were apparently taken to eliminate the threat of down-cutting of the stream channel, and ultimate failure of the culvert itself.

Prairie Fish Assemblages

This project proposes to investigate the effects road culverts may have on warm-water fish species in the lower Yellowstone River drainage. The types of fish found within these systems can best be described as prairie-fish assemblages. Fish that inhabit these waters differ from those populations in mountainous areas in that they can typically withstand the higher stream temperatures and lower dissolved oxygen levels associated with this arid environment. Many of these fish, while not being angled for directly, serve a recreational purpose by being used as bait. Additionally, these fish constitute a large number of the native fish found in Montana. The following discussions will describe some of the life history information and fish assemblage theories related to a project of this nature.

Life History

Life history information about many of the species found in the proposed study area is limited. A literature review of the life history and swimming/leaping capabilities of 27 species of warmwater fish was conducted in Minnesota (Newbrey et al. 2001). Information about the swimming and leaping capabilities was limited, but investigators found that 21 of the 27 species did exhibit upstream migratory behavior at some point in the season (Newbrey et al. 2001). While the large amount of species diversity found in prairie streams makes broad-scale life history statements difficult, some general conclusions can be made in their regards. Most of the fish associated with prairie environments can be classified as spring-spawners (Brown 1971). This is most likely due to intermittent conditions that typify these streams later in the summer. Many species migrate from large rivers into smaller tributaries to spawn, and then will return to their larger bodies of water. The juveniles of these fish will then rear in these tributaries until spring runoff re-distributes them throughout the system (Newbrey et al. 2001). Upstream-migration barriers can adversely affect this type of spawning behavior. The upper reaches in small, prairie-streams may be reduced to isolated pools, or may even completely dewater as summer progresses. The fish that are left in these isolated pools are subject to depredation from other fish and birds. Additionally, isolated pool conditions may favor some species, but detriment others, leading to loss of species in those reaches (Ostrand and Wilde 2004). Therefore, when the water returns in the springtime, it is essential for migrant fish to be able to re-colonize these areas.

Spatial/Temporal Variation

It has been well documented that prairie-fish assemblages are not uniform in distribution. Much of this observation is consistent with the River Continuum Concept (Vannote 1980), which shows that there is a gradient of physical habitat from headwaters to mouths. This gradient of physical habitat results in a spatial and temporal differences in species composition throughout these drainages (Schlosser 1987; Ostrand and Wilde 2002). This spatial variation usually amounts to high densities on small fish, mostly cyprinids, in the upper reaches, and decreased numbers of cyprinids in the lower reaches (Schlosser 1987; Ostrand and Wilde 2002). This decrease is likely related to higher numbers of predator-species found near the mouths of smaller streams (Schlosser 1987). The upper reaches are usually dominated by cyprinids due to their ability to live in stressful situations including low dissolved oxygen and elevated water temperatures (Rahel and Hubert 1991; Ostrand and Wilde 2002). Additionally, a longitudinal distribution of size classes can also occur, with larger fish being found downstream.

These differences in fish assemblage structure can make determining the effects of migration barriers difficult (Schlosser 1990). In this case, differences in species composition between areas upstream and downstream of a road crossing could be due to impassibility, or the result of the natural spatial variation in that system. Species composition can also vary temporally in prairie systems. As mentioned earlier, fish migrate into these streams during spring spawning, but may not be present later in the summer. In contrast, emergent juvenile fish may be more prevalent later in the summer, emphasizing the need for culverts to pass a wide range of species and size classes throughout a wide range of water levels.

Implications of Barriers

Fish movement throughout prairie-stream systems has been well documented. Cyprinids, which were once assumed to be stationary in regards to their home ranges, have been shown to migrate for spawning purposes (Linfield 1985; Lucas 2000; Bonneau and Scarnecchia 2002), and also to move from resting to feeding habitats (Clough and Ladel 1997). If culvert crossings are found in the systems these fish inhabit, then passage considerations should be made. Upstream migration barriers could initiate the loss of species in areas that chronically dewater. Winston et al. (1991) identified the extirpation of four cyprinids as a result of dam construction on a prairie stream in Oklahoma. While there are immense differences between dams and culverts, this example shows how a total barrier can result in a decrease in species richness above that barrier. The arid environment exemplified by eastern Montana streams makes fish passage essential to species continuity as these streams are constantly in a state of flux between extirpation and recolonization.

Study Objectives

1. Examine the physical and hydraulic characteristics of culverts associated with fish passage
2. Examine how species and total length of fish affect passage capabilities
3. Examine how passage capabilities influence the longitudinal distribution of prairie fish

Hypotheses and Predictions

1. Culvert crossings do not represent upstream barriers to prairie fish species.

   P1. Culverts will create velocity barriers for some species/size classes.

   P2. Culverts will create water depth barriers for some species/size classes.

   P3. Outlet drop height will create barrier conditions to upstream migrating fish.

2. The FishXing model will accurately predict the passage capability of road culverts in eastern Montana prairie-streams.

   P1. FishXing will underestimate fish's ability to pass culvert crossings

3. The distribution of fish within prairie streams will not differ between culvert-crossed reaches and natural reaches.
   - P1. The number of species found above a culvert crossing will differ from below.
   - P2. The size of fish found above a culvert crossing will differ from below

Methods and Materials

Study Area

The Yellowstone River drainage was chosen for this project for its species rich tributaries found in its lower reaches. The geography of this area is typified by relatively low precipitation, and soils that have little capacity to hold water (Morris et al. 1981). As a result of this soil capacity, hydrographs regularly show flashy responses from storm and runoff events. Therefore, culverts must typically be sized to accommodate large amounts of water, even though normal flows may be lower than average for those sized pipes. Runoff typically occurs in two peaks. The first occurs in late winter/early spring, and is caused by snowmelt in the lowland areas. This is followed by an early summer peak from the higher elevation snowmelt (Elser et al. 1980).

The proposed study area is located near the town of Glendive, in the northeastern portion of Montana. Several direct tributaries of the Yellowstone will be chosen based on the following criteria: 1) the stream must flow water long enough to ensure warm-water fish presence during both high and low flow periods, and 2) culvert crossings must be present in reaches of streams commonly used by fish species. Much of the land adjacent to bodies of water in eastern Montana is privately owned; therefore, landowner agreement is another variable that will ultimately determine site selection. Culvert material type will not be used to select sites, as a variety of materials and substrate types are preferable.

The proposed study streams include: Sand Creek, Clear Creek, and Fox Creek. All three streams encounter several crossing structures before joining the Yellowstone River. Agriculture is the predominant land use in the proposed study area, therefore making irrigation a necessity for common crops such as sugar beets, corn, and pinto beans. The Glendive Unit of the Buffalo Rapids Irrigation Project is an irrigation canal system that runs from Fallon to Glendive, Montana. This large canal serves 13,254 acres of land along the northwest bank of the Yellowstone River (U.S. Department of the Interior, Bureau of Reclamation 2005). Built between 1939 and 1941, the Buffalo Rapids canal intersects with several of the tributaries that flow southerly into the Yellowstone River. Most streams have siphons installed, and the canal has no direct interaction with the actual stream. However, head-gates are installed upstream of the siphons in the canal, and water is periodically released back into the tributaries for irrigational purposes, as well as to accommodate the channel constrictions at the siphon entrance. This periodic release of water to the tributaries can be quite large according to water demands, and appears to have altered the channel morphology of stream reaches below the canal intersection. Additionally, the number of fish entering the system via the canal, and the effect this irrigation water has on streamflow and chemical properties remains unknown (Morris et al. 1981). However, advantages of this canal system do exist for a project of this type. We wish to investigate fish passage at varying water flows, and the nature of this canal-release system will allow us to study fish at several different flow levels, and for a longer duration during months where some streams may dewater.

Species Composition and Distribution

Tributaries of the lower Yellowstone river system regularly contain rich fish assemblages. Preliminary explorations of tributaries near Glendive, Montana have shown that up to 20 different species of fish can be found in some streams (Montana Rivers

Information System, MFISH). Therefore, any study on fish movement and passage capability must account for this degree of species richness. Additionally, most streams in the proposed study area also display a longitudinal distribution of fish species throughout their length, with increasing species diversity as one progresses downstream (Vannote et al. 1980; Schlosser 1990). This longitudinal gradient of fish species, coupled with a temporal change in fish assemblage, makes sampling the entire stream system important to account for all species involved in this study (Matthews 1990; Ostrand & Wilde 2002).

Species composition and relative abundance will be measured by randomly sampling several reaches throughout each study stream. Fish-sampling reaches will be 300 m in length to ensure that all representative species are collected (Patton et al. 2000). Two, 300-m, sites will be established between the mouth at the Yellowstone River and the lowest road crossing, as well as two sites between each additional road crossing as one continues upstream in the system. At each site, fish will be captured using 0.25-inch mesh seines. Seining will progress downstream, with individual hauls being occurring every 10 to 20 meters, or as habitat characteristics require (Bramblett standard protocol 2005). Fish will then be placed in aerated live-wells, and will be measured for total length, and identified to species. Voucher samples of up to five fish per species will be preserved in a 10% formalin solution, and retained for identification confirmation; otherwise, all fish will be returned live to the stream. Each site will be sampled during spring and summer seasons to account for temporal variation.

Electrofishing would normally be the standard procedure for sampling fish in small stream systems. However, ambient conductivity of many streams found within the proposed study area routinely exceeds 1000 μS/cm. Conductivities this high have been shown to decrease the effectiveness of electric fields on fish species (Reynolds 1996; Hill 1994). Additionally, many streams in eastern Montana are characterized by high turbidity, and elevated temperatures. We feel that electrofishing in these systems, in addition to being ineffective, could also result in increased fish mortality due to poor netting visibility and added stress on species experiencing high water temperatures. Therefore, seining will be used as the primary sampling method during both the species composition/distribution study, as well as the direct assessment experiments.

Seining has been shown to be an acceptable method for determining species composition in streams of this nature (Patton et al. 2000). However, information using seining as a technique for mark-recapture studies is relatively scarce. A possible complication in this method lies in the efficiency to capture all fish within a given section. Habitat features, turbidity, and sampler error all could affect this efficiency. Therefore, we will conduct studies to determine the sampling efficiency of our seining techniques in each of the proposed study streams. These studies will be conducted after the completion of a species composition/distribution survey to utilize the fish collected from the survey. The efficiency study will entail using two seines to block a random 100-m reach of stream. All fish collected during the species composition survey will then be batch-marked using Bismarck Brown Y dye, and allowed to recover in an aerated live well. This dye was chosen for to its ability to mark numerous fish for short-term studies, and its relatively low mortality rate (Rinne & Deacon 1973). All fish will then be released at the midpoint of the 100-m reach, and allowed to re-distribute throughout the blocked reach for approximately 30 to 45 minutes. Seining will then be performed in three consecutive passes through the blocked reach. After each pass, the number of dyed fish will be recorded, and the dyed fish will be held in aerated live wells while the next pass is conducted. These studies will allow us to determine the capture efficiency of a known number of fish per single pass with a seine. This information will be used to quantify the percentage of fish that may not be recaptured during the direct assessment studies.

Habitat features and turbidity are other factors that may affect capture efficiency. Therefore, a Lamotte turbidity meter will be used to measure turbidity before each capture efficiency study. Habitat classification by haul may also be incorporated into this efficiency test, but will only be useful if the same classification and haul system is applied to the direct assessment experiments as well (Winston 2004).

Utilization of the FishXing Model

FishXing (Six Rivers Watershed Interactions Team 1999) uses physical and hydraulic measurements, and swimming and jumping capabilities of fish to predict whether fish can successfully navigate through culverts, or if the crossings act as barriers for some or all species at specific water levels. Many of the species traditionally used in the model are from the family Salmonidae; however, several predominant species in the proposed study streams are also available for use in the model. These species include: common carp, flathead chub, dace, stickleback, longnose sucker, and white sucker.

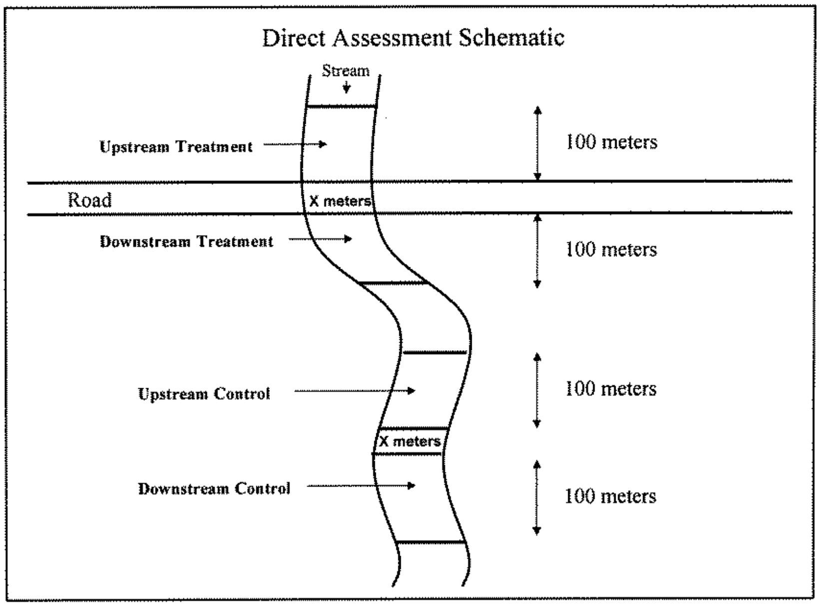
The physical and hydraulic measurements will be collected according to the protocol described in the USFS San Dimas Technology and Development Center's *National Inventory and Assessment Procedure for Identifying Barriers to Aquatic Organism Movement at Road-Stream Crossings* (WilsonMusser et al. 2002). Measurements will include culvert shape and dimensions, culvert material, corrugation dimensions, bottom type, plunge pool and tailwater depth. Culvert length, slope, and channel cross sections will also be recorded using survey equipment and the assistance of an engineer. Discharge will be measured at each stream crossing using a velocity meter in conjunction with a standard top-setting rod. The USGS Six-tenths-depth method for measuring discharge will be used because the majority of study sites routinely experience water depths between 0.3 feet and 2.5 feet (USGS, Buchanan 1969; Rantz et al. 1982). This method of measuring discharge uses the velocity at 60% of the water depth to estimate average velocity. The data collected will be used in FishXing to assess all culverts within the proposed study area for each of the earlier mentioned fish species. The species in FishXing with the weakest swimming capability will be used as a conservative estimator of fish passage for species found in study streams, but not listed in the software model.

Direct Assessment Experiments

Fish movement through culverts within the proposed study area, will be examined through the use of a mark-recapture type of experiment. Each experiment will entail delineating stream reaches upstream and downstream of a culvert crossing (Figure 1). The stream will be divided into 100-m reaches above and below an individual culvert. These reaches will be identified as Upstream Treatment (UT) and Downstream Treatment (DT) respectively. Two additional 100-m reaches will be established downstream of the Downstream Treatment reach. These two reaches will be separated by a "Theoretical Culvert", and will be identified as Upstream Control (UC) and Downstream Control

(DC). The Theoretical Culvert will be a distance of natural stream equal to the length of the actual culvert in the experimental reach.

Figure 1: Direct Assessment Schematic



Fish will be first collected in the Upstream Treatment reach using 0.25-inch mesh seines. Seining will be conducted in the same manner as in the fish distribution surveys. All fish will be placed in an aerated live well to ensure that incidental mortality is avoided. Depending on stream conditions, an additional seine pass may be required to increase sample size. Once 50 fish of each of the predominant species have been collected, fish will be identified to species, measured to total length, and marked using a Visible Implant Elastomer (VIE) tag, with tag color unique to each sampling reach.

VIE tags were chosen as the method of marking because of their adaptability to a number of species and size classes, and because we felt they would have the least effect on fish swimming capability. According to the manufacturer of the VIE tags (Northwest Marine Technology), fish as small as 9 mm have been tagged with their equipment.

However, for practical purposes, only fish greater than 60 mm will be tagged for these experiments. Initial trials have shown that the proximal margin of the anal fin is a suitable tag location in most species found within the study area. Interspecific body type and color difference, as well as tagging error, can affect the retention of VIE tags. The unknown loss of tags can adversely affect mark-recapture experiments. Therefore, a pilot study to determine the retention of VIE tags will be necessary (Roberts and Angermeier 2004). This study will involve tagging a known number of fish representing the predominant species and size classes, and placing them in a cage within the stream for three days. Fish will then be examined for VIE tags, and a percentage representing retention rates after three days will be calculated. Other techniques such as batch dying fish with either Bismarck Brown or Rhodamine Blue dye may be used to mark fish smaller than 60 mm.

Marked fish will be allowed to recover in another aerated live well, and then released in the next pool habitat below the plunge pool created by the culvert. Block nets will then be installed at the upstream end of the Upstream Treatment reach, and at the downstream end of the Downstream Treatment reach. The entire process will then be repeated for the Upstream and Downstream Control reaches, with fish being marked by a different color VIE, and fish being relocated below the Theoretical Culvert.

The reasoning behind this active manipulation of fish has to do with the homing tendency of fish to return to their home range after displacement. Evidence exists in the literature that many species of warm-water fish use this homing tendency to return to natal streams for spawning (Linfield 1985), and to return to resting areas after migration to and from feeding areas (Clough & Ladle 1997). We believe that by displacing fish downstream of a culvert, or Theoretical Culvert, the natural instinct of fish to return to their original location will provide motivation to swim through our reach of interest (Burford 2005).

The control and experimental reaches will remain blocked for a period of three days. During this time, the fish will be allowed to move within the upstream and downstream reaches, but cannot leave at either end. Due to an abundance of organic material found in these types of streams, efforts will be made to reduce the amount of material build-up on the block nets. This will be accomplished through the use of screens installed upstream of each block, and through active monitoring of the screens and block nets. After the fish have had the allotted three-day period to move within this system, we will then sample each of the four, 100-m reaches (UT, DT, UC, DC) using multiple pass seining. Fish will be placed in aerated live wells, and will be examined for VIE tags, identified to species, and measured to total length. Any fish with VIE tags collected upstream of the actual or Theoretical Culvert will be considered to have passed through the reach of interest. Fish captured below either of these culverts will be assumed to have remained stationary.

These experiments will be run at each of the road crossings within our study streams a minimum of three times. This will allow us to examine fish passage during spring runoff, early summer (post-runoff), and late summer (low flow). From these experiments, we will be able to determine if any of these culverts present an upstream barrier during any portion of the year.

Hydrology of the Study Streams

The in-stream hydrology of the proposed study streams is an essential component in both direct and indirect assessment of fish passage. Real-time water height will be monitored in the actual culverts, as well as in the streams themselves through the use of data logging instrumentation that records water height, water temperature, and air temperature (TruTrack). These instruments will be mounted in stilling wells (Rantz et al. 1982). Site location will be located as close as possible to the culvert, and will follow the guidelines described in the USGS *General Procedure for Gaging Streams* (USGS, Carter & Davidian 1968). The instruments will be set to record data once every hour. In conjunction with these instruments, we will also take a minimum of five discharge measurements near the stilling well. These discharge measurements will allow us to correlate water height and stream discharge, and a predictive rating curve will be built to estimate discharge from water height recorded on our instrumentation (USGS, Carter & Davidian 1968). Additionally, inlet and outlet depths will be measured in the actual culverts periodically, and this information will also be related to the water height recorded on the data logger. The rationale here is that if we know the discharge of water through the culvert, and we know the surface area of the water, then we can use the equation Q (discharge)= Σ[V (Velocity) * A (Area)] to find the average velocity of the water flowing through the culvert (Chow 1959). This information on velocity will be used to determine if FishXing is over or underestimating the swimming capabilities of certain species, and will also be used to show average velocities throughout the duration of the direct passage experiments.

Data Analysis

The following are some descriptions of how the data will be used for determining fish passage through culverts, and for determining physical and hydraulic characteristics that dictate successful passage.

Fish Passage Through Culverts

The control versus treatment nature of the direct assessment of fish passage will allow us to compare the degree of movement of fish between culvert reaches, and reaches that represent the natural stream characteristics. Comparisons between control and treatment groups will include the number of species successfully passed, and the lengths of fish successfully passed. Analysis of this data will likely be accomplished using Chi-square tests, in which the observed versus expected numbers of fish that have moved through the actual and theoretical culverts will be compared.

Physical and Hydraulic Characteristics Determining Fish Passage

Multiple linear regression will be used to predict the probability of fish passage through culverts. Predictor variables for this analysis could include: average velocity, culvert material, outlet drop height, culvert barrel water depth, stream temperature, species, and total length of fish. The rating curve produced from our data logging equipment will provide the average velocity during direct and indirect assessment. The results of this regression analysis will be used for comparisons with our results from both direct and indirect assessment.

Timeline

Date(s)	Event(s)
Spring 2005	• Attend classes MSU Bozeman • Site selection • Literature review of sampling/marking techniques, hydraulic data collection, culverts/fish passage, and prairie fish assemblages • Attend prairie fish identification workshop • Obtain all necessary equipment/supplies • Obtain scientific collection permit • Meet with project committee to discuss study design • Create landowner relations for access to private lands
Summer 2005	• Installation of stilling wells/TruTrack data loggers • Collection of hydraulic and biologic data • Exploration of potential future culvert crossings • Progress reports
Fall 2005	• Attend Classes MSU Bozeman • Data entry and organization • Voucher sample verification • Annual report for Montana Fish, Wildlife and Parks (MT FWP) • Removal of stilling wells for winter storage • Write research proposal • Progress Reports
Winter 2006	• Oral Examination • Present project at Great Plains Fisheries Workers meeting Glasgow, Montana
Spring 2006	• Purchase additional materials and supplies • Installation of stilling wells (Late February) • Additional site selection • Begin collecting biologic and hydraulic data • Hire 1 field technician and secure housing in Glendive, Montana • Attend Western Regional AFS meeting, Bozeman, Montana
Summer 2006	• Collection of biologic and hydraulic data • Progress reports
Fall 2006	• Attend classes MSU Bozeman • Data entry and organization • Data analysis • Begin writing thesis • Annual report for MT FWP
Winter 2007	• Thesis writing
Spring 2007	• Completion of thesis • Defense of thesis • Present findings at Montana Chapter of the American Fisheries Society annual meeting

Budget

Category	Expense	Cost	
		2005	**2006**
Personnel	Graduate Student Tuition and Fees ($2,650/semester x 2 semesters) Stipend ($1,200/month x 12 months)	 $5,300 $14,400	 $5,300 $14,400
	Field Technician 1 Undergraduate Field Technician $7.00/hour x 4 months (@40 hrs/wk)	$4,480	$4,480
Equipment	1 Four-color visual implant elastomer tagging kit (1 additional kit will be purchased in 2006 for more color options)	$400	$400
	1 Gurley pygmy flow meter	$650	
	1 Aquacalc 5000 flow meter indicator	$1,150	
	6 TruTrack data loggers @ $200 each	$1,200	
	1 Lamotte turbidity meter	$900	
Supplies	Stilling well materials, 2 pair of breathable chest waders, 2 pair wading boots, one 15'x4' seine, one 20'x6' seine, 2 cooler/aerator livewells, 2 rechargeable batteries, 12 minnow traps, one Palm handheld computer, other materials	$1,980	$1,080
Travel and Housing	Travel-Personal Vehicle 10 trips x 900 miles/trip x $0.395	$3,555	$3,555
	Housing 4 months x $250/month	$1,000	$1,000
	Conferences 2 conferences/year x $500	$1,000	$1,000
Totals		**$36,015**	**$31,215**

Total Estimated Cost: $67,230

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